



Status and plans for reanalysis at NASA/GMAO

Mike Bosilovich
on behalf of the GMAO

CERES Science Team Meeting, Langley Research Center, May 2018

Toward an Earth system reanalysis capability

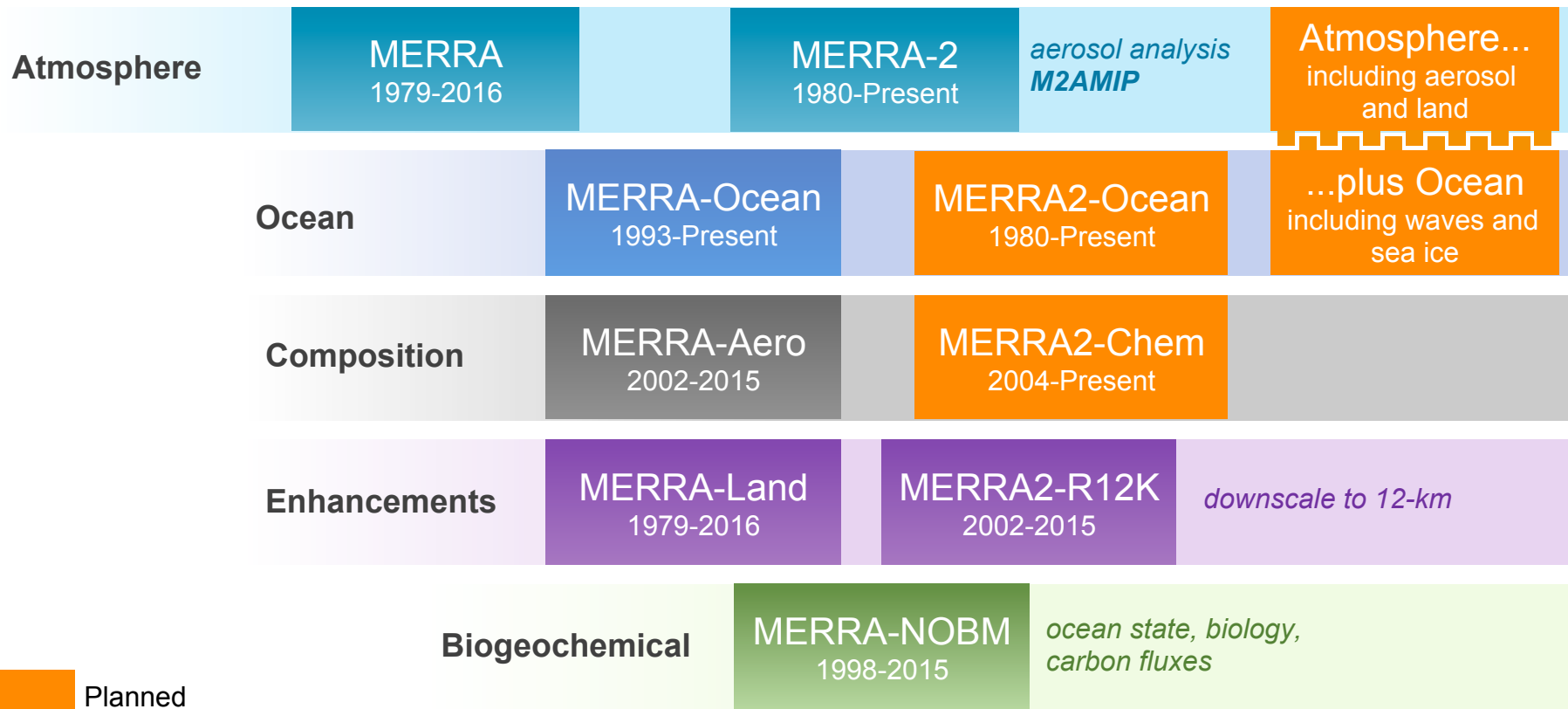
- GMAO is active in extending its GEOS system to encompass many aspects of the Earth system
- Progress incrementally through a combination of systems with increased levels of coupling, plus offline component reanalyses
- GMAO's work links strongly to NASA's Earth observations
 - ▶ Use of GEOS products by instrument teams **(FP, FP-IT and GEOS 5.4)**
 - ▶ Ingest of NASA data to demonstrate their value in Earth system analyses
 - ▶ Planning for new NASA missions

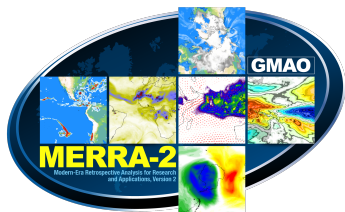
This talk focuses on a few examples that illustrate current capabilities and are steps on the pathway to future growth

GMAO reanalyses and derivative products

2010

2020






Some aspects of MERRA-2

- GMAO's most recent atmospheric reanalysis of the modern satellite era
- Advances over its predecessor, MERRA (Ceased production 29 Feb 2016)
 - ▶ Many more observations
 - ▶ Model and analysis updates
- **Focus on non-meteorological aspects as a pathway to a more complete Earth system reanalysis**
 - ▶ Aerosol data assimilation
 - ▶ Representation of cryospheric processes
 - ▶ Use of NASA observations in the stratosphere, especially ozone
- Well documented, including a special collection in *J. Climate*



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 4.161* (#7)

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Journal of Climate
 July 2017, Vol. 30, No. 14
 Published online on June 20, 2017
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☐ **A Satellite-Derived Lower-Tropospheric Atmospheric Temperature Dataset Using an Optimized Adjustment for Diurnal Effects (1508 times)**
[Carl A. Mears](#) and [Frank J. Wentz](#)
Journal of Climate
 October 2017, Vol. 30, No. 19
 Published online on August 30, 2017
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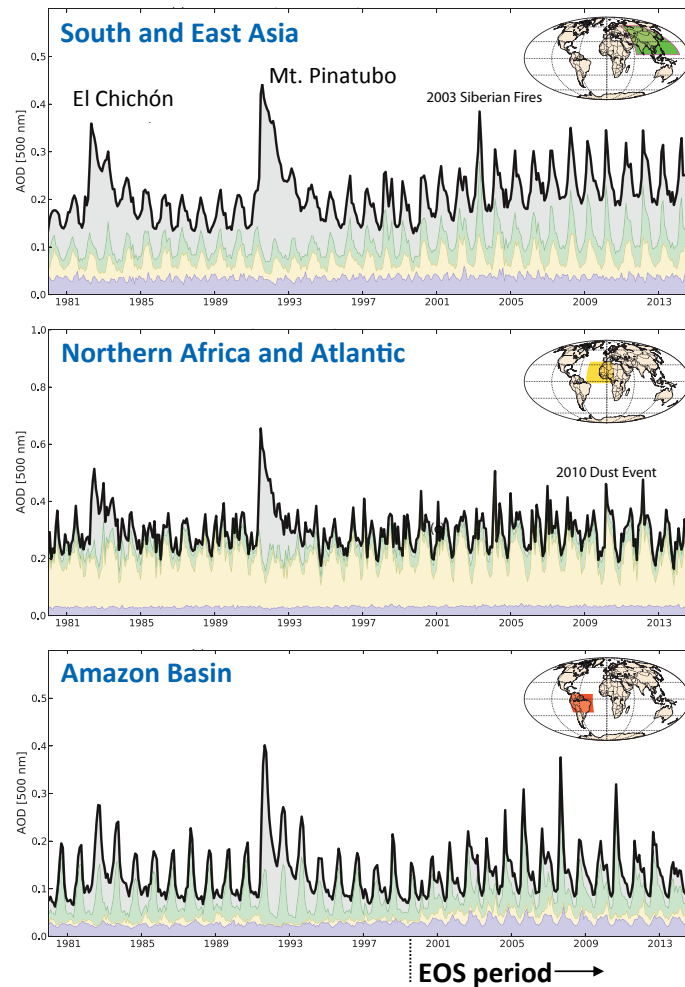
MERRA-2 Aerosol Analysis

Total AOD —
Sea Salt —
Dust —
Carbonaceous —
Sulfate —

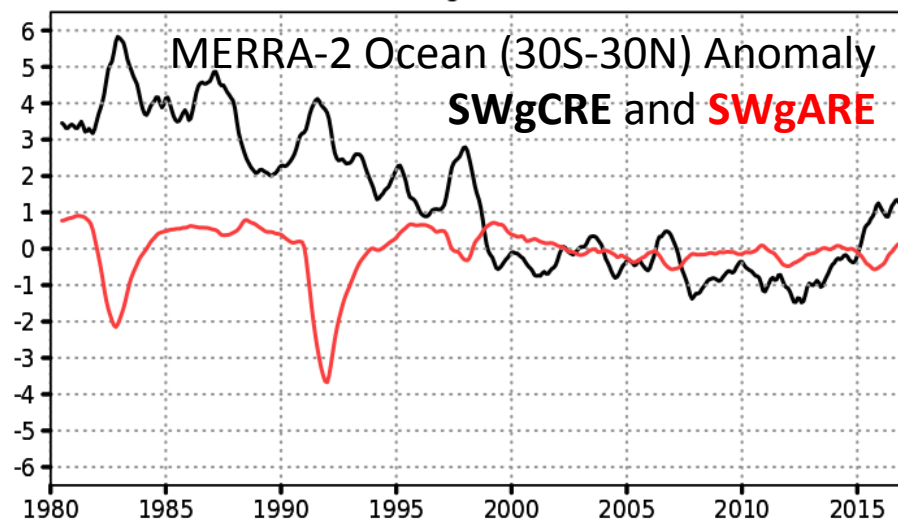
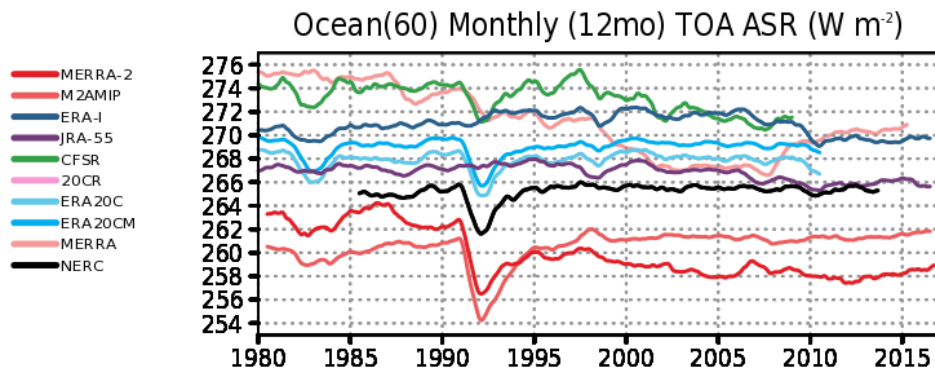
Time series of AOD in MERRA-2 averaged over major aerosol source regions (1980 – 2014)

Seasonal cycles of dust and biomass burning apparent in all regions, as are large increases in sulfate after El Chichón and Mt. Pinatubo eruptions

Dominant aerosol types generally differ by region, e.g. dust over Africa, carbon from biomass burning over Amazon

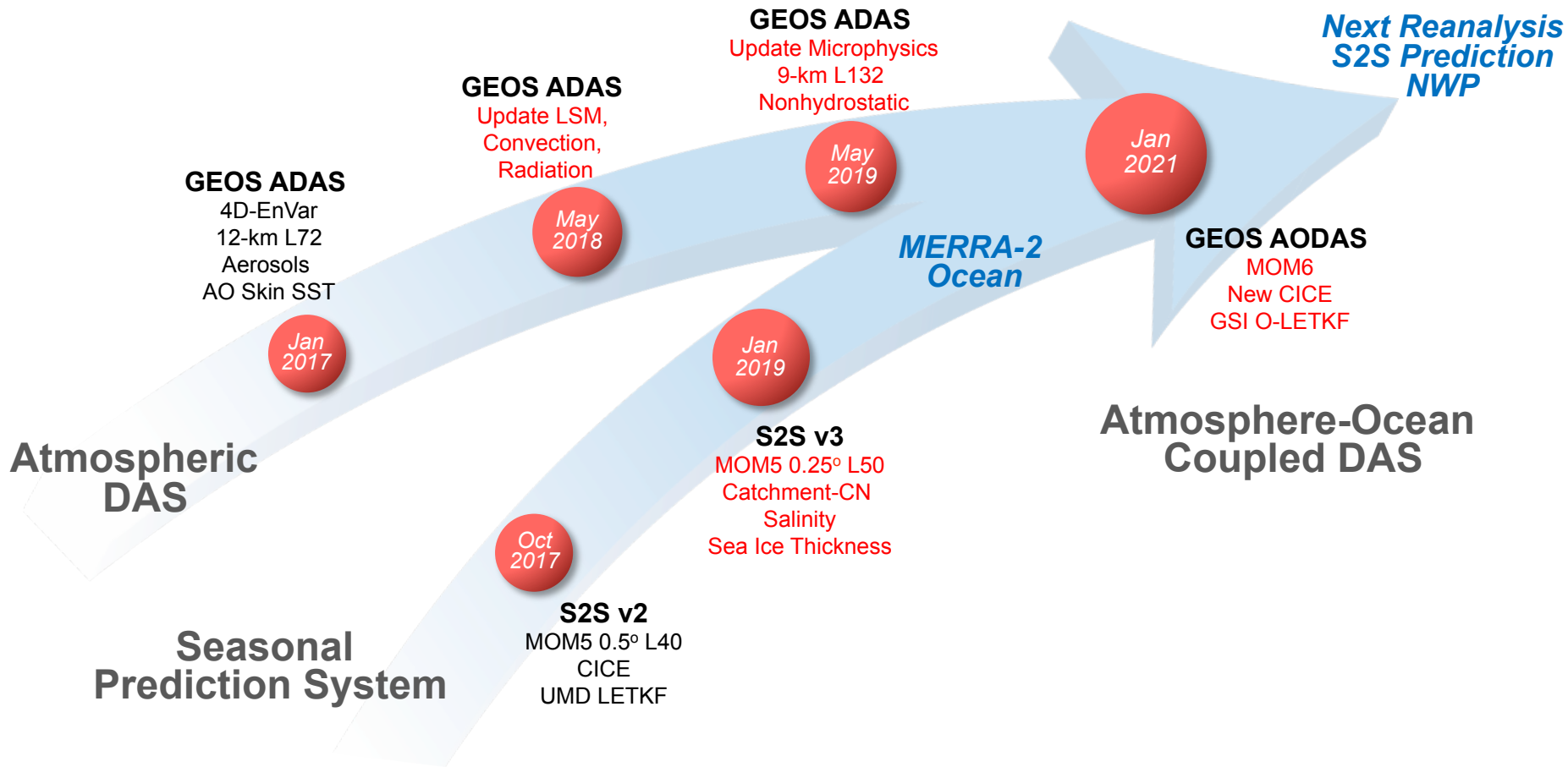


An Aside: M2 SW Aerosol and Cloud Effect

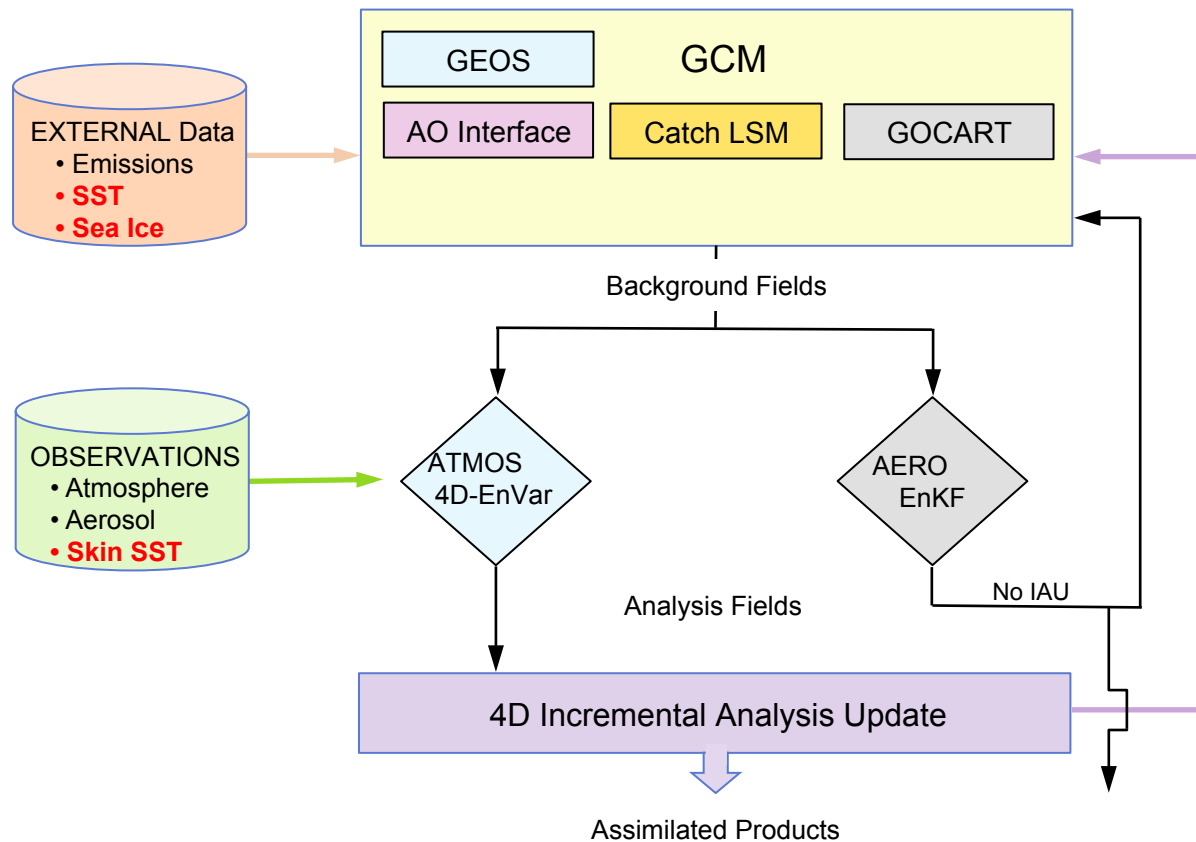


- MERRA-2 exhibits increasing reflected SW radiation through its history, leading to too strong imbalance at TOA during the CERES period
- While significant changes occur around the eruption and dissipation of Mt. Pinatubo aerosols, the imbalance is more related to cloud effects
- Water vapor assimilation affects the clouds, increasing reflected SW

GMAO coupled atmosphere-ocean assimilation development



Current GEOS atmospheric assimilation system



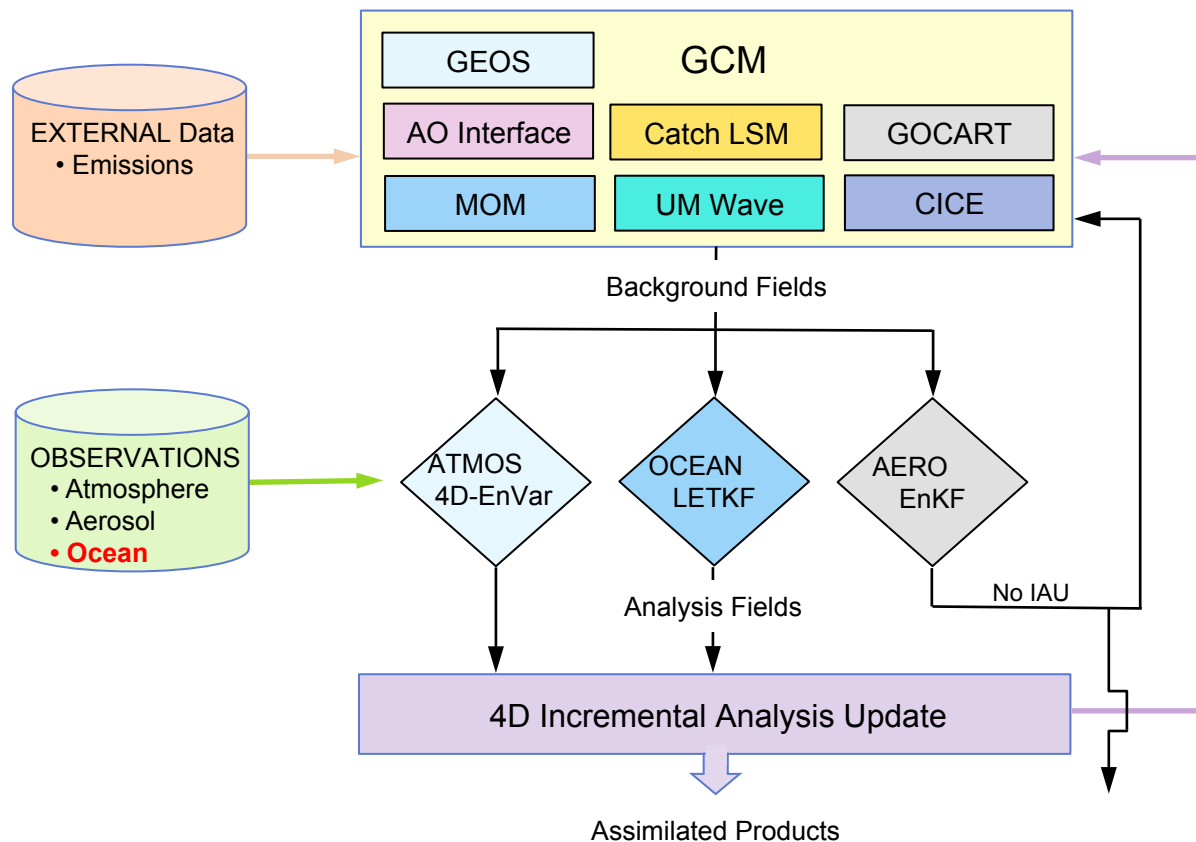
Atmospheric DA including aerosols and skin SST

Background fields from the GEOS AGCM

Separate analyses for **atmosphere** and **aerosols**

Aerosol feedback to atmosphere via AGCM radiation

Planned GEOS coupled atmosphere-ocean assimilation system



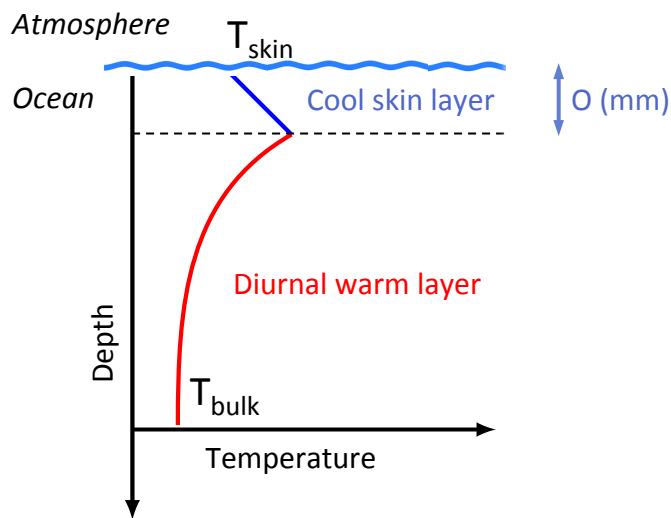
Coupled DA for the atmosphere and ocean

Background fields from the **coupled** GEOS AOGCM

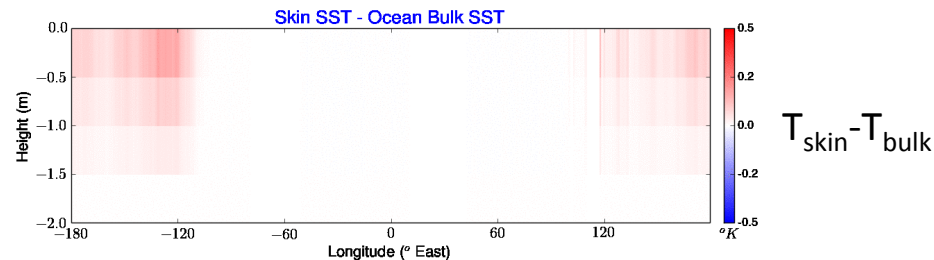
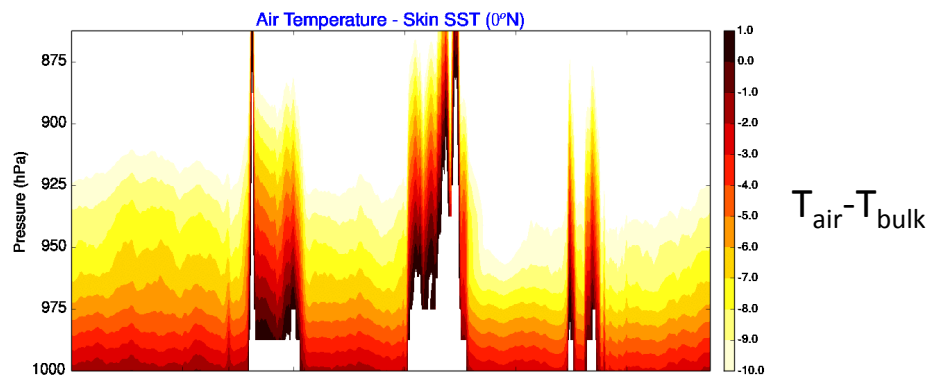
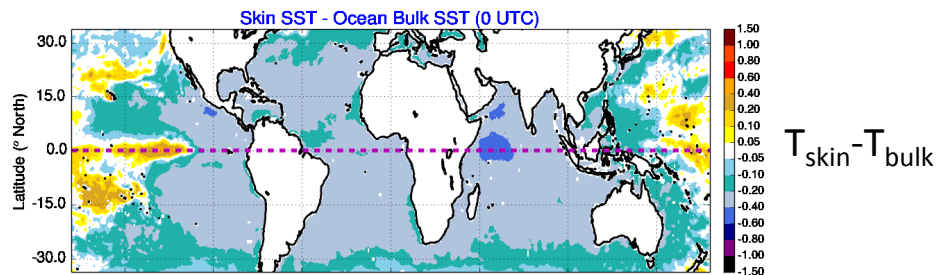
Separate analyses for **ocean**, **atmosphere** and **aerosols**

Information exchange between ocean and atmosphere occurs through IAU model integration (and eventually "outer loops")

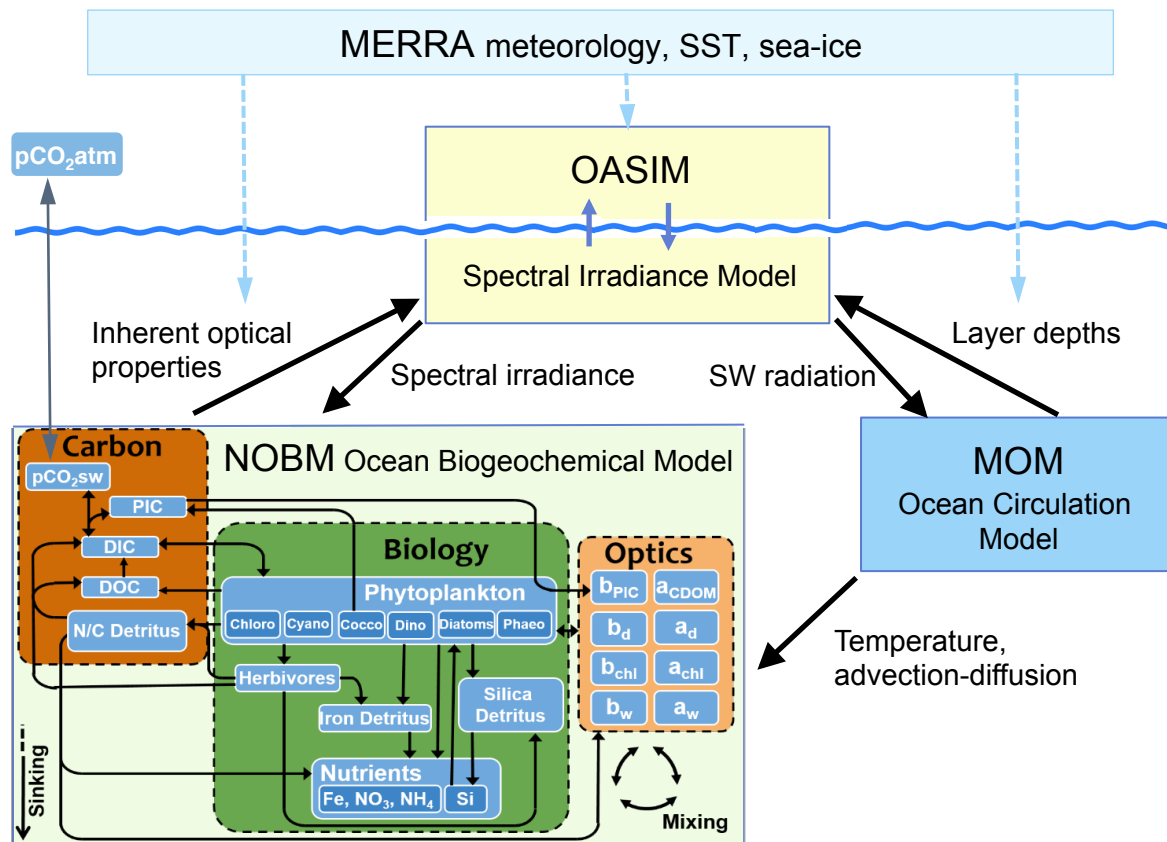
GEOS semi-coupled skin SST analysis (AO interface)



- Model diurnal cycle, with cool skin plus diurnal warming in 2-meter mixed layer
- Assimilates SST-sensitive IR radiances plus all other data in the atmospheric analysis
- Eventually, T_{bulk} from coupled ocean model



Ocean biogeochemical assimilation



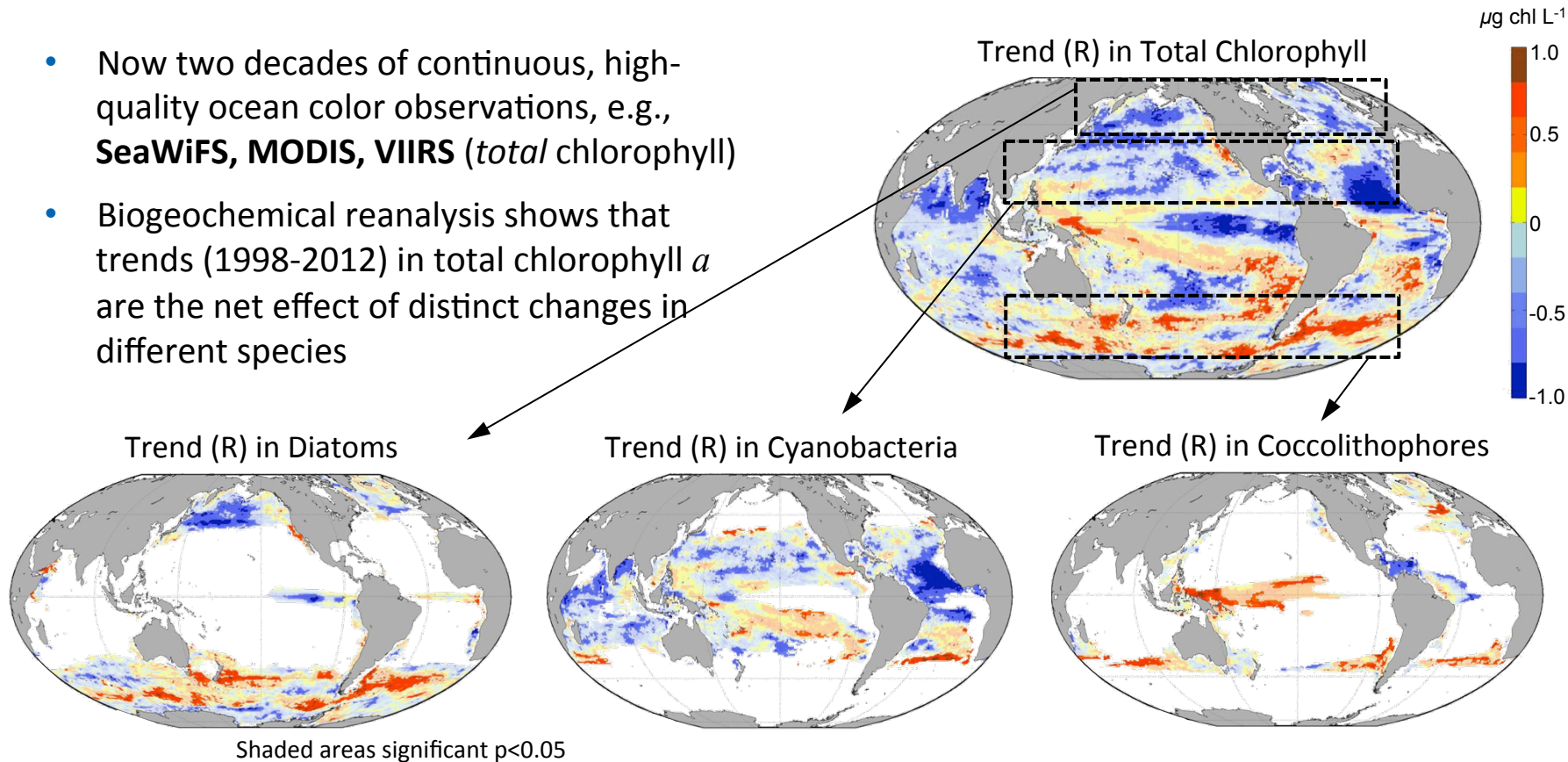
NASA Ocean Biogeochemical Model (NOBM)

Assimilates chlorophyll, absorption of colored dissolved organic matter (CDOM), and particulate inorganic carbon (PIC)

Outputs chlorophyll, nutrients, phytoplankton groups, primary production, nutrients, carbon components and fluxes, spectral irradiance/radiance

MERRA-NOBM global decadal trends in ocean phytoplankton

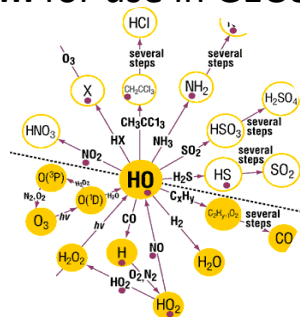
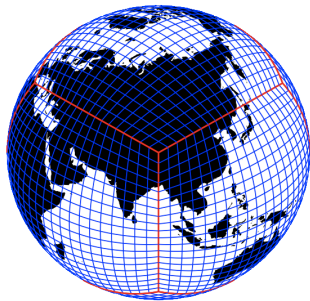
- Now two decades of continuous, high-quality ocean color observations, e.g., **SeaWiFS**, **MODIS**, **VIIRS** (*total chlorophyll*)
- Biogeochemical reanalysis shows that trends (1998-2012) in total chlorophyll *a* are the net effect of distinct changes in different species



Rousseaux and Gregg, 2015, *Glob. Biogeochem. Cycles*.

Three-dimensional chemistry

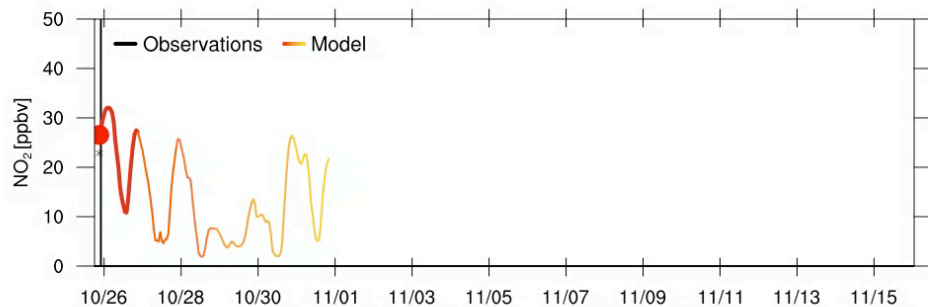
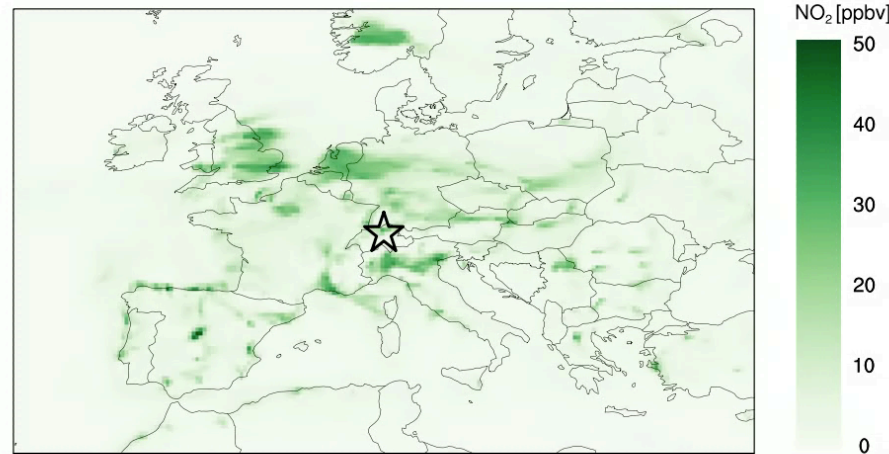
Long-standing collaboration with Harvard to develop **GEOS-Chem** for use in GEOS

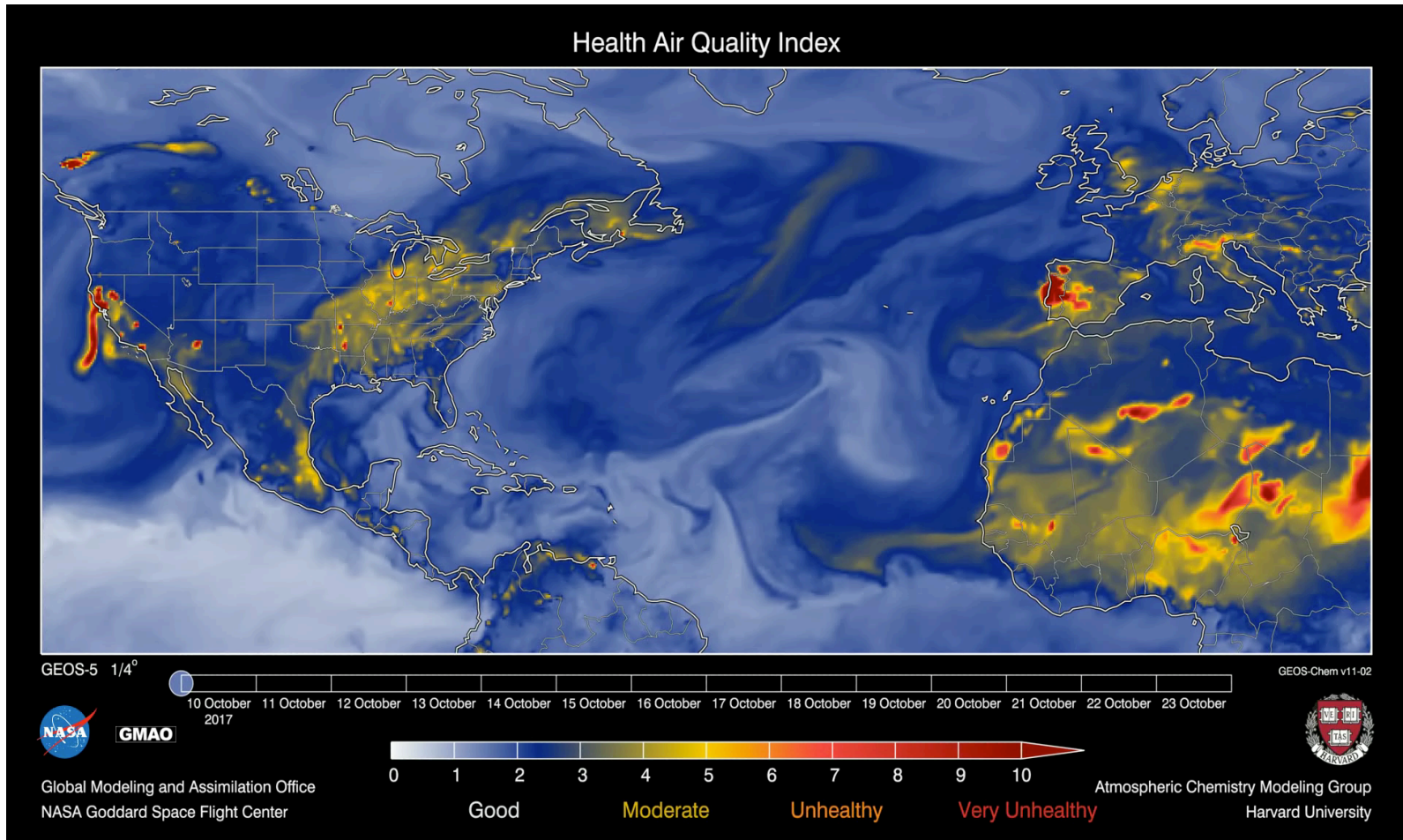


As a research project, recently began daily full chemical forecasts at 25-km resolution, forced by GEOS real-time meteorology

Currently, no assimilation of chemical species, but this will be worked in slowly as a separate optimization from the met state (**OMI, MOPITT, ...TEMPO, Sentinel, GEMS**)

Zurich, Switzerland, 2017-10-26 00:00 UTC





HAQI shown here combines O_3 , NO_2 and $PM_{2.5}$

CERES-GMAO Evaluation Group

- Routine Telecons (~3 weeks)
- Relate status and updates
- Review GEOS versions, Algorithm sensitivity
- Eventually consider system sensitivity to Component Analysis
- **GEOS Checkpoint Experimentation**
 - Test new GEOS versions over a specified period(s), maintain a history of changes
 - Prepare for CERES 5.0 (and next reanalysis)
 - Configuring to run at NASA Ames
- GEOS **v5.4** (FP-IT, MERRA-2 is 5.12, FP is 5.19)
- Need to define **reanalysis requirements** for next CERES reprocessing
 - If coupled Earth is not it, we may be very close to a candidate

Summary

- GMAO is working toward an integrated Earth system analysis capability to advance its activities in S2S, reanalysis and NWP
- A reanalysis with coupled physical components of the atmosphere, ocean, land and cryosphere is **planned for 2021 (duration/period and exact system configuration TBD)**
- Given GMAO's focus on the use of NASA observations, ongoing research is aimed at the representation of aerosols, chemical, and biogeochemical processes
- Continue production of MERRA-2 (and FP-IT and 5.4), and MERRA-2-driven component reanalyses that serve as test environments for emerging capabilities